

What is claimed is:

1. An apparatus for treating a surface of a workpiece at approximately atmospheric pressure, said apparatus comprising:
  - a. a chamber for containing a plasma;
  - b. a first inlet having a first inlet orifice for admitting a plasma gas into said chamber;
  - c. a microwave radiation pathway connectable to a source of microwave radiation, wherein microwave radiation in said microwave pathway generates plasma from said plasma gas, said plasma being centered on a plasma core and having an inner plasma zone adjacent said plasma core and an outer plasma zone adjacent said inner plasma zone;
  - d. a second inlet having a second inlet orifice for admitting a working gas into said chamber, wherein said working gas generates excited species, said excited species of said working gas not having deleterious interaction with said plasma whereby substantial disintegration of said excited species is avoided; and
  - e. an outlet from said chamber for allowing said excited species to exit said chamber.
2. An apparatus according to claim 1, further comprising a plasma concentrator disposed within said chamber, said plasma concentrator concentrating said plasma at a predetermined location within said chamber, whereby said plasma core is juxtaposed with said plasma concentrator.
3. An apparatus according to claim 2, wherein said plasma concentrator comprises a rod, said rod being axially-symmetrically disposed within said chamber.
4. An apparatus according to claim 2 wherein said chamber has walls with an interior, wherein said plasma concentrator comprises a hollow ring, said ring having a periphery, said periphery of said ring inscribing said chamber walls, whereby said working gas can flow through said hollow ring of said plasma concentrator.
5. An apparatus according to claim 4 further comprising a second plasma concentrator, said second plasma concentrator comprising a hollow ring, said

second plasma concentrator being disposed intermediate said first plasma concentrator and said outlet, whereby plasma is generated intermediate said first plasma concentrator and said second plasma concentrator.

5           6.     An apparatus according to claim 1, further comprising a window transparent to microwave radiation and disposed on a wall of said chamber, said microwave radiation transmitting through said window into said chamber.

10           7.     An apparatus according to claim 1, wherein said second gas inlet orifice is disposed intermediate said first inlet orifice and said outlet.

            8.     An apparatus according to claim 1 comprising a plurality of second inlet orifices, each for admitting a working gas into said chamber.

15           9.     An apparatus according to claim 1 comprising a plurality of first inlet orifices each for admitting a plasma into said chamber.

20           10.    An apparatus according to claim 7, further comprising an igniter for initiating the exciting of said plasma gas into a plasma.

            11.    An apparatus according to claim 10, wherein said igniter is removable from said chamber.

25           12.    An apparatus according to claim 10, wherein said igniter comprises a dielectric barrier discharge device.

            13.    A method of plasma treating a surface of a workpiece at atmospheric pressure, said method comprising the steps of:

30           providing a plasma generating apparatus comprising a chamber for containing a plasma, a first inlet having a first inlet orifice for admitting a plasma gas into said chamber, a second inlet having a second inlet orifice for admitting a working gas into said chamber, an outlet from said chamber allowing a gaseous species to exit said chamber, and a microwave power supply for providing microwave radiation to said chamber and generating plasma from said plasma gas, whereby said  
35           plasma excites said working gas to create an excited species which exits said outlet to treat the surface;

supplying plasma gas through said first inlet and into said chamber;  
providing microwave radiation from said microwave power supply to said plasma  
gas;  
generating a plasma from the plasma gas using said microwave radiation;  
5 supplying working gas through said second inlet to said chamber, wherein said  
working gas bypasses said first inlet orifice so that said working gas has minimal  
deterioration due to contact with the plasma;  
exciting said working gas using the plasma to create an excited gaseous species;  
juxtaposing said outlet with the workpiece to treat a surface of the workpiece; and  
10 applying a treatment of the excited species to the surface of the workpiece at  
approximately ambient pressure.

14. A method according to claim 13, wherein said plasma is generated at a pressure from  
about 200 Torr to about 2,500 Torr under dynamic operating conditions.
- 15 15. A method according to claim 14 wherein said plasma is generated at atmospheric  
pressure.
16. A method according to claim 13, further comprising the step of moving said  
20 apparatus about said workpiece, thereby treating different portions of said surface of  
said workpiece.
17. A method according to claim 14, wherein said step of supplying said plasma gas  
comprises the step of supplying an inert gas.
- 25 18. A method according to claim 13, wherein said step of supplying said working gas  
comprises supplying a working gas having a dual functionality, said dual  
functionality providing a source for generating said plasma and a monomer for  
generating said excited species.
- 30 19. An apparatus according to claim 5 further comprising an first attenuator juxtaposed  
with at least one said plasma concentrator and being disposed radially outboard thereof.,  
20. An apparatus according to claim 9 comprising a microwave power supply for each of  
said first inlets.